Goddard Space Flight Center, Greenbelt

SOHO

Wheels speeds optimization for maneuvers

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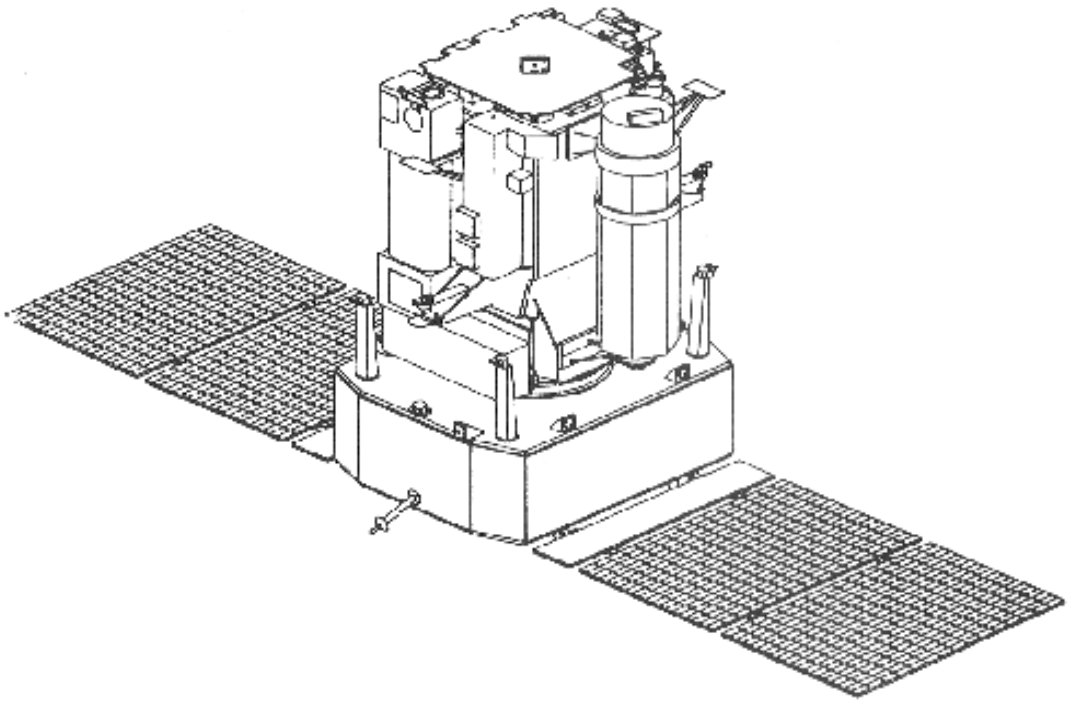

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1 SOHO maneuvers every three months

1.1 Why perform maneuvers every quarter?

In May 2003, the SOHO High Gain Antenna (HGA) got stuck along Z-axis.
During the summer, many unsuccessful attempts were performed to free it. A movement along Z-axis remains possible thru a dual coil command but this is not regarded as a standard way to proceed.
The antenna has then been parked at the so-called “sweet spot” position (Z angle = -17.8969 deg), which allows keeping contact with earth and consequently maintains SOHO mission, under the following conditions:

- Unless 70m dish stations are available, the High Rate telemetry downlink cannot be used during periods of several days every quarter known as “keyhole periods”.
- A 180 degrees roll maneuver has to be performed during the keyholes (March, June, September and December).

1.2 Maneuvers scheduling

With the roll to be performed every three months and the regular Station Keeping (SK) and Momentum Management (MM) maneuvers performed approximately every four months, it has been decided to perform all maneuvers (SK, MM and Roll) every three months.
The first maneuver performed in the sequence is the SK. To take advantage of the already heated cat beds, SK is followed by the MM. Eventually comes the 180 degrees roll maneuver.
Thus, the typical sequence of a maneuver is:

- Station-keeping
- Momentum Management
- 180 degrees roll

2 Wheels speeds optimization

As more and more missions use Deep Space Network resources (in particular Mars missions), it is more and more difficult to obtain both 70 m and 34m station slots. When obtained, they are generally of short period of time and there is no margin left when scheduling a whole Station-keeping, Momentum Management and 180 deg roll sequence.

The purpose of the performed Wheel Speed Optimization study has been to find standard wheel speed triplets whose characteristics are:

- To limit as much as possible the momentum management durations (which also saves fuel)
- To allow easy long term scheduling
- To guarantee the system robustness in case of maneuver abortion

3 Study hypotheses and constraints

3.1 Wheel speeds

The wheels are positioned at the four corners of a pyramid base. Three out of four are actually used (1, 2 and 3).
In the satellite reference frame, all wheels have a +X torque projection. Wheel #1 (resp Wheel #3) has also a +Z (resp –Z) torque projection, while Wheel #2 has a –Y torque projection.

To avoid too large disturbances and in order to maintain the Hx at a reasonable value after the 180 degrees roll maneuver, the wheel speeds cannot be too high, in particular the wheel #2 speed.

3.2 Disturbance torques

A close look at the disturbance torques shows that these are almost constant and an average value could be considered as a reasonable hypothesis.
The values taken into account in the study are:
Tx = 4.5 E-07 Nm
Ty = -1.3 E-07 Nm
Tz = -1.5 E-06 Nm

3.3 Momentum Management frequency

As stated in section 1.2, a momentum management is now scheduled every three months. Nevertheless, solutions based on a momentum management every six months have also been studied. The results are very interesting and show that one out of two momentum managements can be skipped.

3.4 Perihelion

The perihelion fluctuation has been taken into account.
2004: January 4, 18:00 UT
2005: January 2, 01:00 UT
2006: January 4, 15:00 UT

3.5 Wheel Speed limits

The wheel speeds have to remain out of the (-190 rpm, +190 rpm) forbidden zone.

3.6 Validity

A solution cannot be accepted if, in case of aborted maneuver, a wheel speed limit (+/-4000 rpm or +/-190 rpm) is reached within 2 weeks.

3.7 Hx

Hx value must always remain above –10 Nms.

4 The solution

The following cases have been studied:

- Momentum management performed every three months
- Momentum management performed every six months with Hx optimization
- Momentum management performed every six months with W2 speed optimization, i.e. never below 400 rpm
- Momentum management performed every six months with thrusters' wall time optimization.

The only one presented here is the latter, since it is the best compromise between maneuver duration, Hx value, wheel speeds values and validity in case of maneuver abortion.

The parameters of this solution are:

- Target wheel speeds after June maneuvers: (-600, -400, 1000)
- Target wheel speeds after December maneuvers: (-400, -400, 1600)

4.1 Table

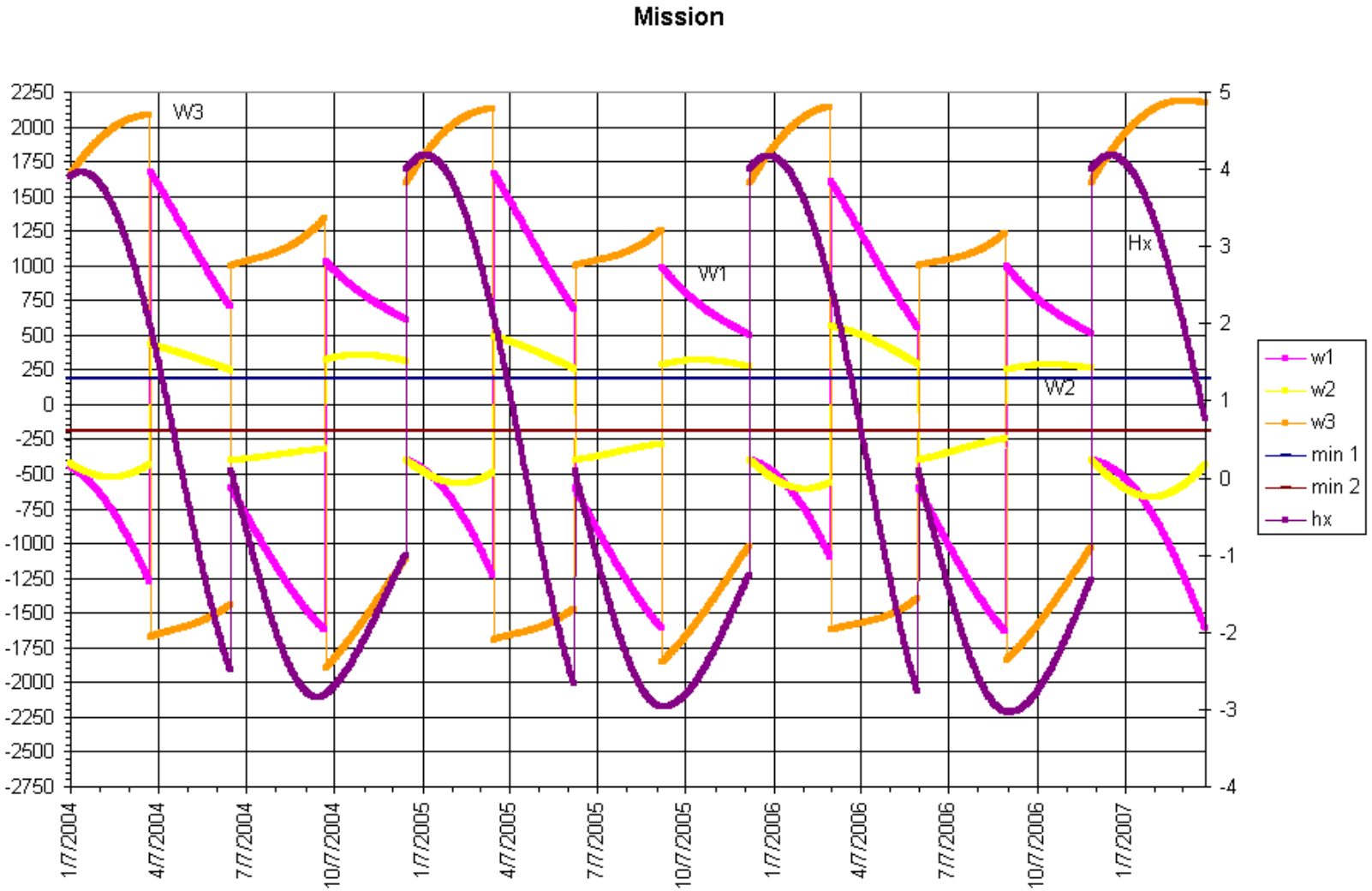
MM every 6 months

(-600/-400/1000) and (-400/-400/1600)

Hypothese: Disturbance torques almost constant (Tx = 4.5e-07; Ty = -1.3e-07; Tz = -1.5e-06)
Perihelion : 4 Jan 2004 18:00; 2 Jan 2005 01:00; 4 Jan 2006 15:00

Date of maneuver	Roll Position after maneuver	WS (1,2,3) before maneuver or roll	WS validity (aborted maneuver or aborted roll)	WS validity (weeks) (aborted maneuver or aborted roll)	WS (1,2,3) after maneuver or roll	Thrusters used and Wall time or remark
30-Mar-04	Regular	(-1270,-430,2090)	12-May-04	6	Roll (1680,430,-1670)	Ok WS while rolling
22-Jun-04	Inverted	(690,250,-1440)	15-Jul-04	3.5	**Type 1 (-600/-400/1000)**	Roll second OK Th (5,2,3); Wall time (6,4,6) min
28-Sep-04	Regular	(-1620,-320,1340)	1-Mar-05	21	Roll (1030,320,-1900)	Ok WS while rolling
21-Dec-04	Inverted	(610,310,-1100)	14-Feb-05	7	**Type 2 (-400/-400/1600)**	Roll second OK Th (5,2,4); Wall time (12,1,4) min
22-Mar-05	Regular	(-1230,-490,2130)	10-May-05	7	Roll (1670,490,-1690)	Ok WS while rolling
14-Jun-05	Inverted	(680,260,-1470)	4-Jul-05	3	**Type 1 (-600/-400/1000)**	Roll second OK Th (5,2,3); Wall time (6,4,6) min
13-Sep-05	Regular	(-1610,-290,1250)	20-Mar-06	25	Roll (980,290,-1850)	Ok WS while rolling
13-Dec-05	Inverted	(500,270,-1020)	17-Feb-06	8.5	**Type 2 (-400/-400/1600)**	Roll second OK Th (5,2,4); Wall time (13,2,6) min
07-Mar-06	Regular	(-1090,-560,2140)	6-May-06	8	Roll (1610,560,-1620)	Ok WS while rolling
06-Jun-06	Inverted	(550,290,-1390)	30-Jun-06	3.5	**Type 1 (-600/-400/1000)**	Roll second OK Th (5,2,3); Wall time (6,3,4) min
05-Sep-06	Regular	(-1640,-250,1240)	3-Apr-06	28	Roll (1000,250,-1840)	Ok WS while rolling
03-Dec-06	Inverted	(500,260,-1020)	9-Feb-07	9	**Type 2 (-400/-400/1600)**	Roll second OK Th (5,2,4); Wall time (13,2,6) min
31-Mar-07		(-1610,-440,2170)				

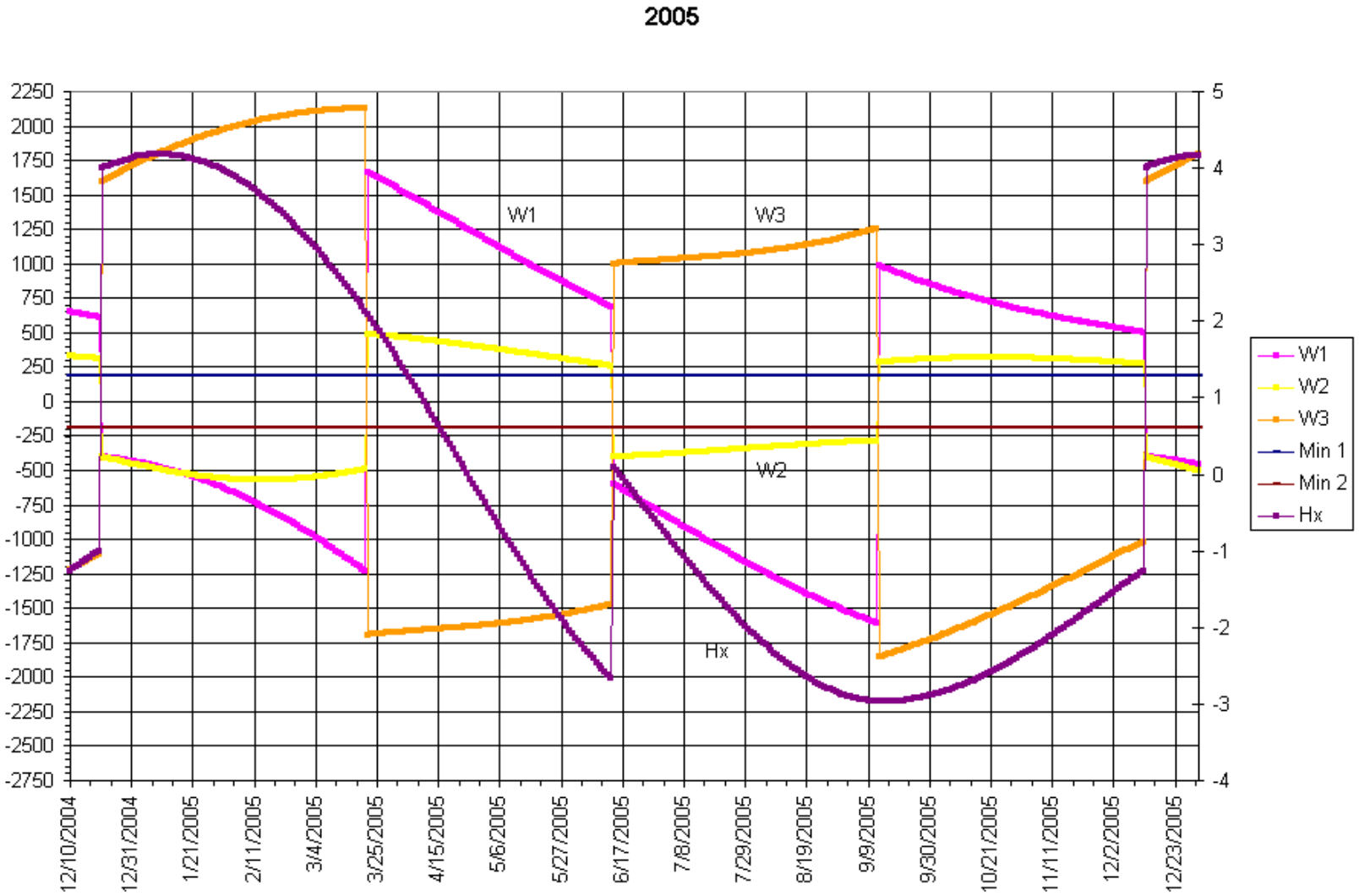
4.2 Wheel speeds and Hx till end March 2007



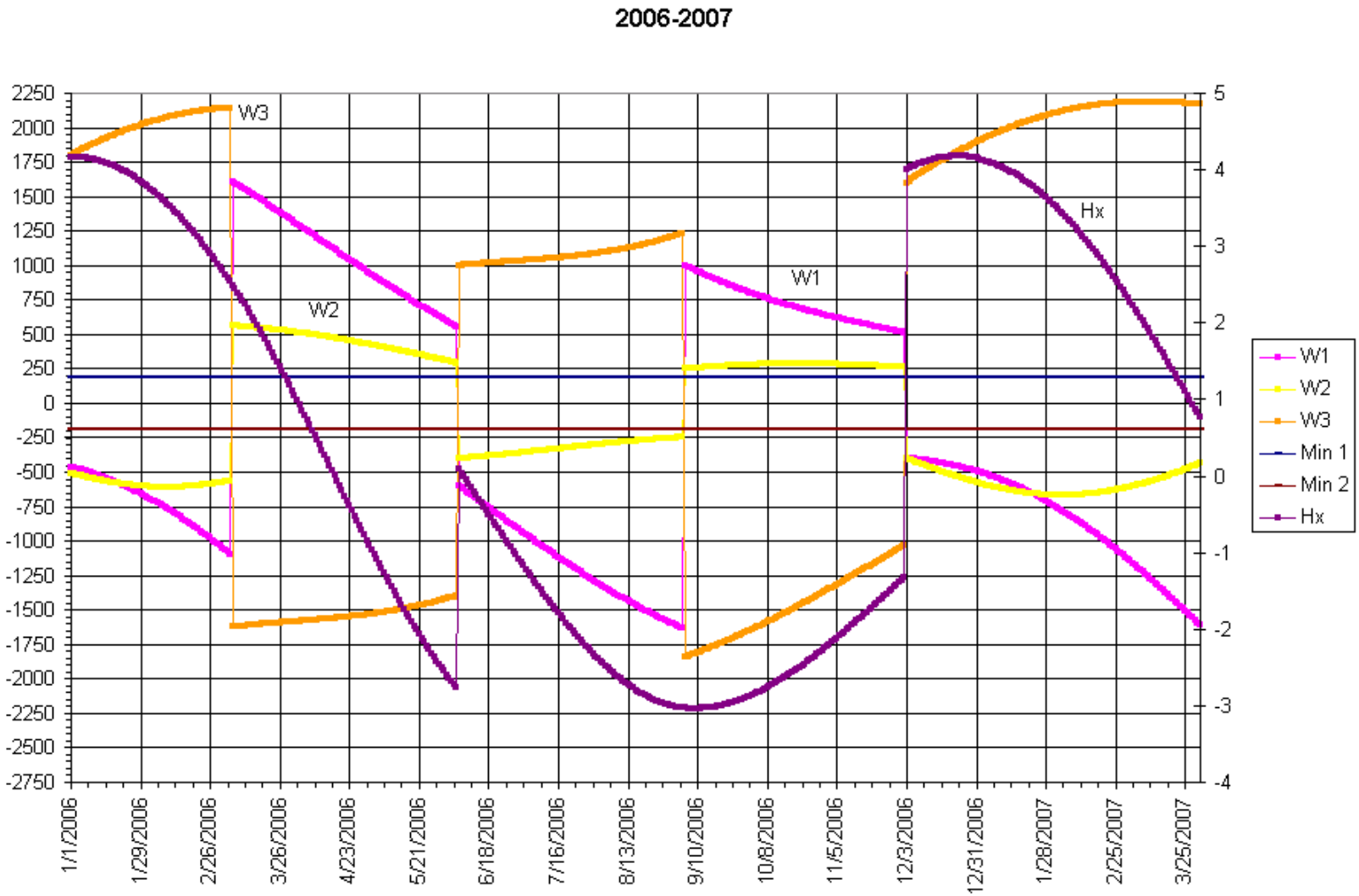
4.3 2004


2004
W3
W1
W2
Hx
w1
w2
w3
min 1
min 2
hx
2250
2000
1750
1500
1250
1000
750
500
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
5
4
3
2
1
0
-1
-2
-3
-4
1/7/2004
1/28/2004
2/18/2004
3/10/2004
3/31/2004
4/21/2004
5/12/2004
6/2/2004
6/23/2004
7/14/2004
8/4/2004
8/25/2004
9/15/2004
10/6/2004
10/27/2004
11/17/2004
12/8/2004
12/29/2004

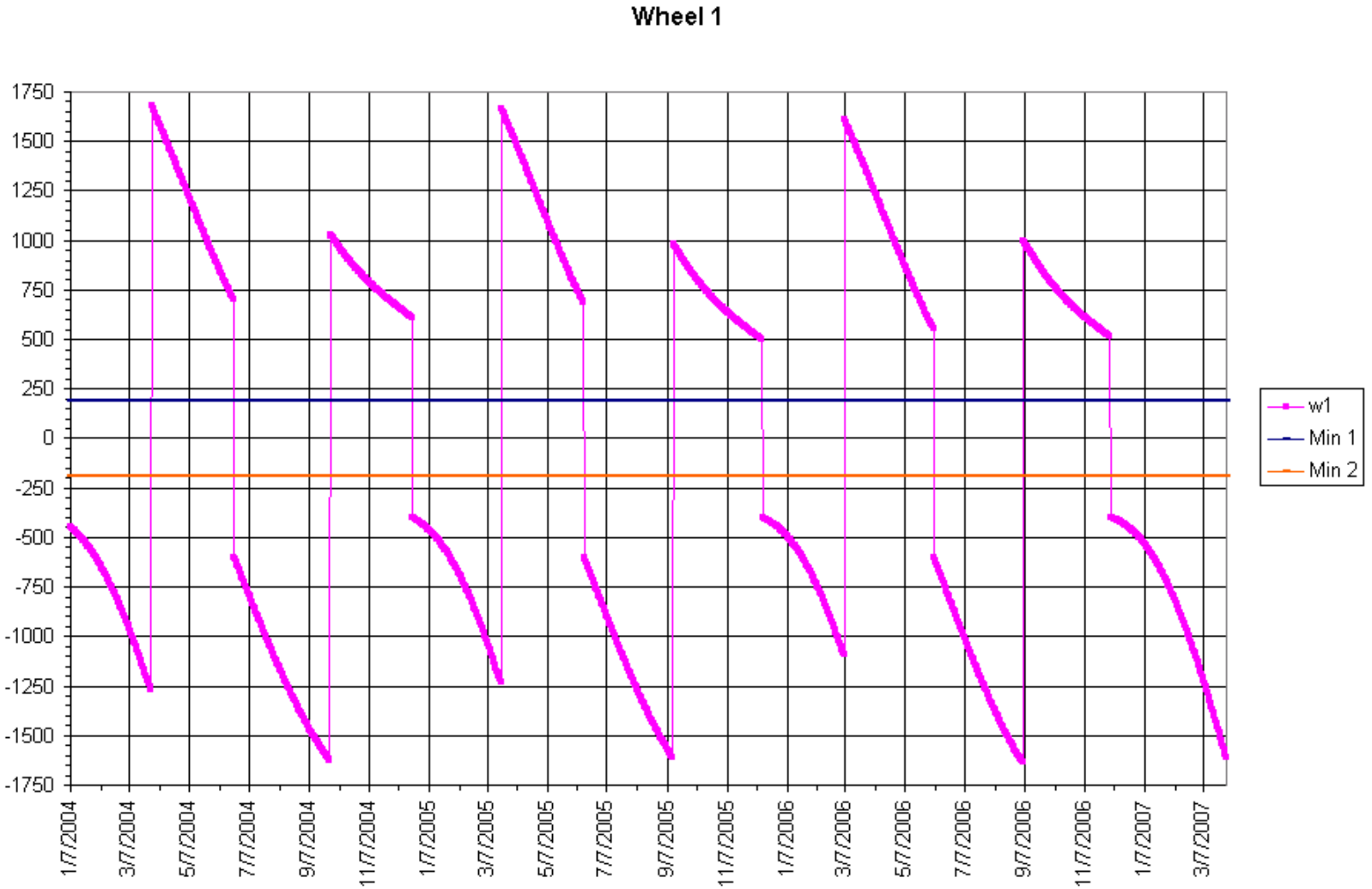
4.4 2005


2005
W1
W3
W2
Hx
W1
W2
W3
Min 1
Min 2
Hx
2250
2000
1750
1500
1250
1000
750
500
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
5
4
3
2
1
0
-1
-2
-3
-4
12/10/2004
12/31/2004
1/21/2005
2/11/2005
3/4/2005
3/25/2005
4/15/2005
5/6/2005
5/27/2005
6/17/2005
7/8/2005
7/29/2005
8/19/2005
9/9/2005
9/30/2005
10/21/2005
11/11/2005
12/2/2005
12/23/2005

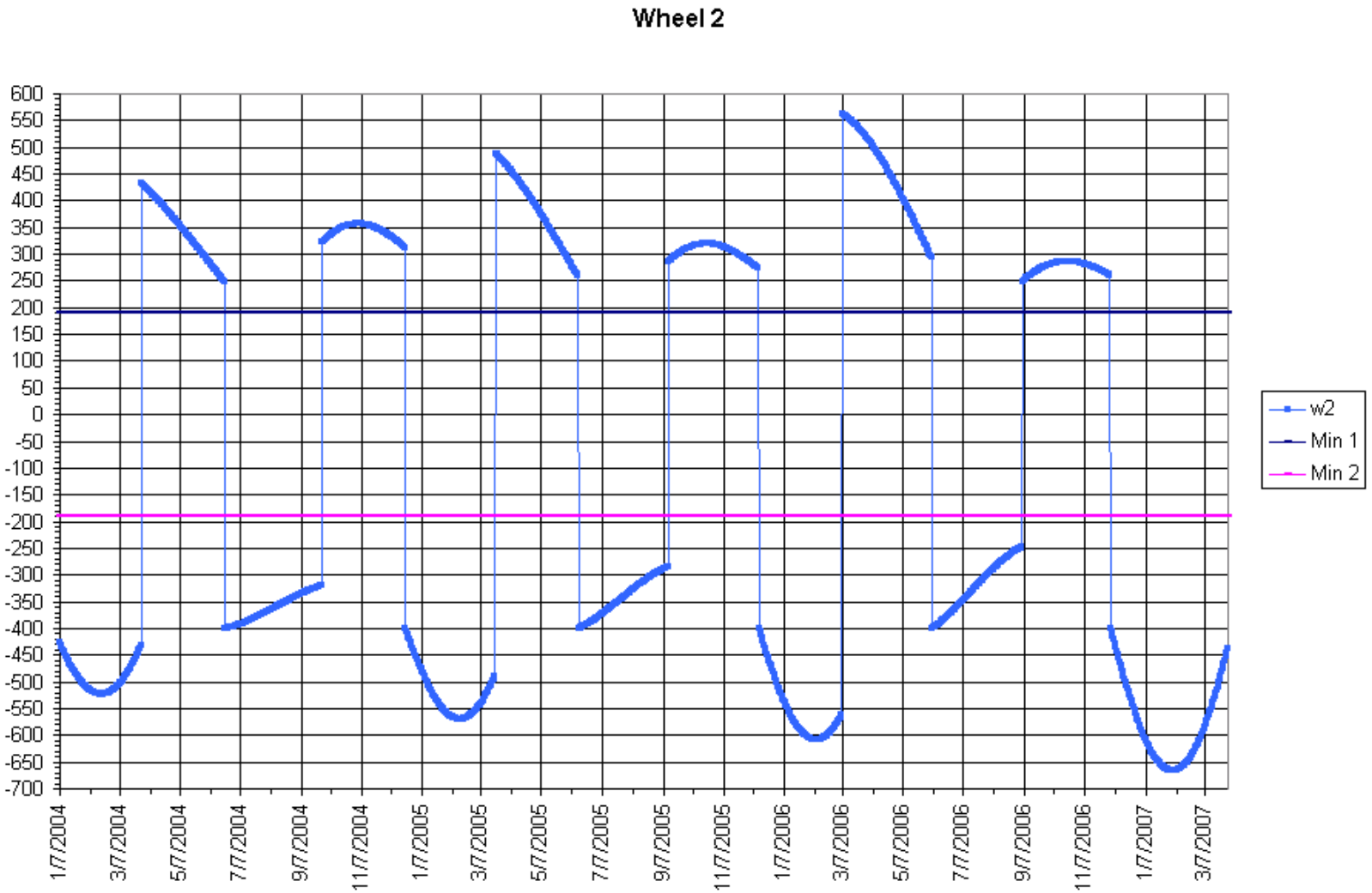
4.5 2006-2007


2006-2007
W3
W2
W1
Hx
2250
2000
1750
1500
1250
1000
750
500
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
5
4
3
2
1
0
-1
-2
-3
-4
1/1/2006
1/29/2006
2/26/2006
3/26/2006
4/23/2006
5/21/2006
6/18/2006
7/16/2006
8/13/2006
9/10/2006
10/8/2006
11/5/2006
12/3/2006
12/31/2006
1/28/2007
2/25/2007
3/25/2007
W1
W2
W3
Min 1
Min 2
Hx

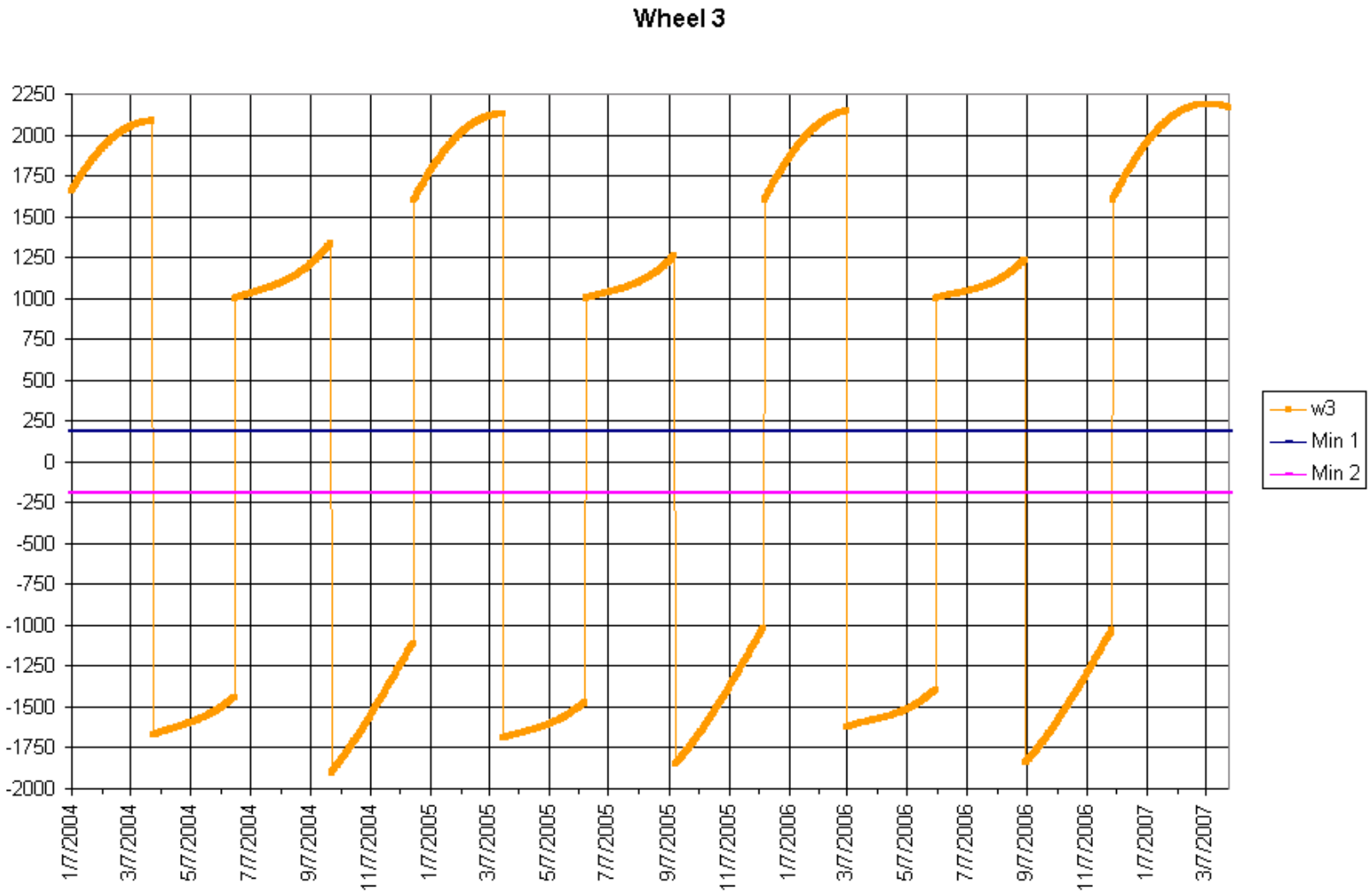
4.6 Wheel 1 speed (2004-2007)



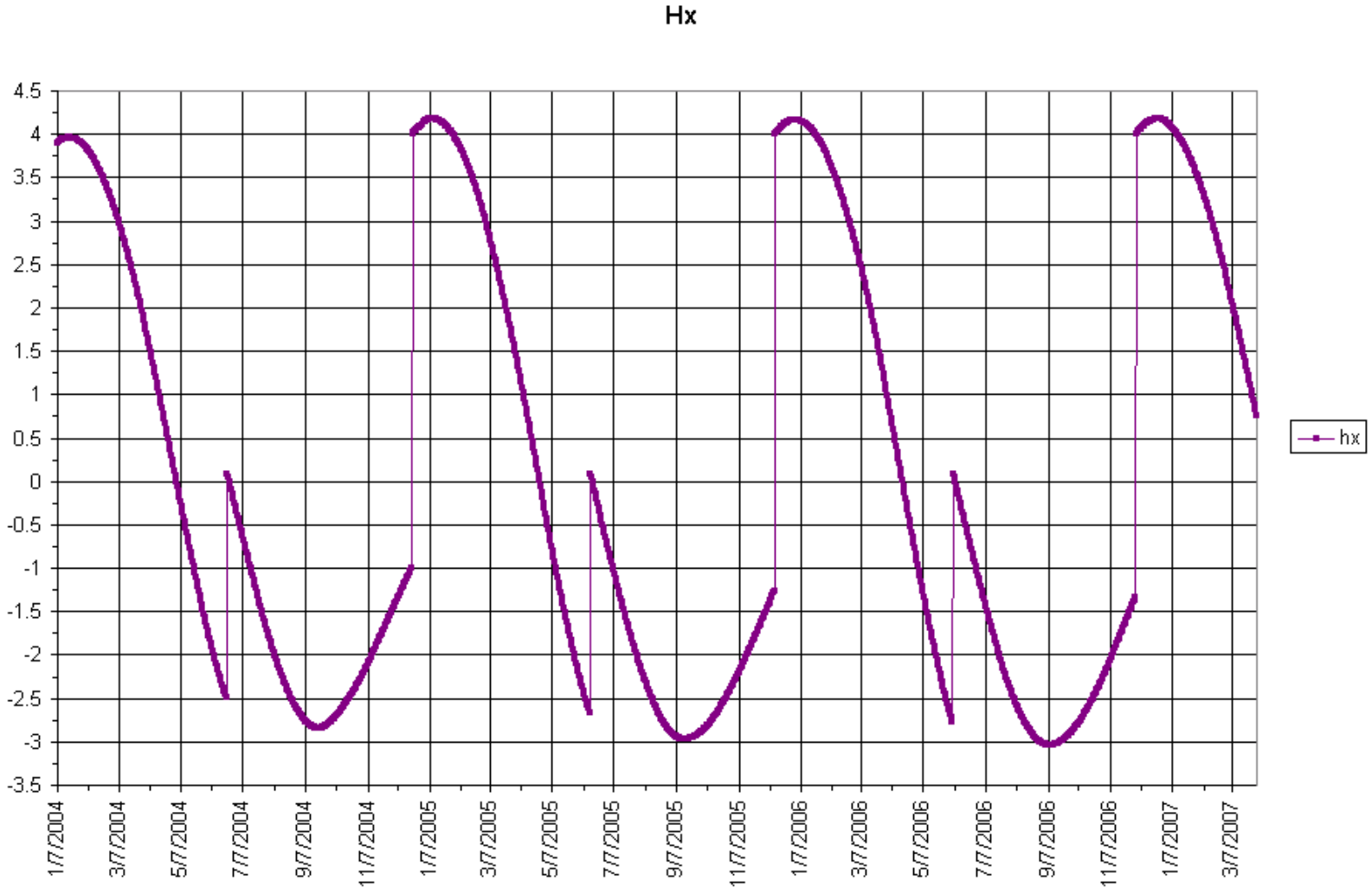
4.7 Wheel 2 speed (2004-2007)



4.8 Wheel 3 speed (2004-2007)



4.9 Hx (2004-2007)



5 Conclusion

A long-term momentum management scheduling is feasible.
The solution proposed, using only two target wheel speeds triplets ((-600, -400,1000) in June and (-400, -400,1600) in December), also provides the following advantages:

- A sufficient time margin for a maneuver rescheduling in case of maneuver abortion
- A standard overall maneuver duration of around 40 minutes (wall time of about 20 minutes) twice a year instead of every quarter.

These target speeds can still be used if a three-month based momentum management remains scheduled. As an example, for March 30 2004, the target speeds after SK, MM and Roll maneuvers would be (-1250, -450, 2150) involving a thrusters (5,1,4) MM sequence with only (101ms, 69ms, 23ms) required on times, corresponding of a 3 minutes total wall time.
The overall maneuver duration will be around 23 minutes, 43% less than a standard MM maneuver.